NUMERICAL SIMULATION OF EM ABSORPTION FOR A PATIENT WITH BRAIN CANCER

Ae-kyoung Lee[(1)], Hyung-do Choi[(2)], Done-sik Yoo[(3)], Hyung-soo Lee[(4)], Jeong-ki Pack[(5)]

[(1)] Radio Science Dept., Electronics and Telecommunications Research Institute, 161 Gajong-Dong, Yusong-Gu, 305-350, Daejon, Korea, E-mail: aklee@etri.re.kr
[(2)] As (1) above, but E-mail: choihd@etri.re.kr
[(3)] As (1) above, but E-mail: dsyoo@etri.re.kr
[(4)] As (1) above, but E-mail: hsulee@etri.re.kr
[(5)] Dept. of Radio Science and Engineering, Chungnam National University, 220 Kung-Dong, Yusong-Gu, 305-764, Daejon, Korea, E-mail: jkpack@hanbat.cnu.ac.kr

ABSTRACT

The electromagnetic absorptions in the normal model and the patient models with brain tumor were simulated with the FDTD technique using the measured dielectric properties of brain cancer and compared for exposure to plane waves of 350, 835, and 1765 MHz and a cellular phone. The results showed the peak SAR and the averaged SAR of eye tissue and lens nucleus of patient models to increase for exposure of plane wave at 350 MHz. The effect of brain cancer on EM absorption increase was relatively slight at 835 and 1765 MHz and SAR decreases appeared strongly in deep areas of the head such as cerebellum, gray matter, cerebrospinal fluid, and nerve.

INTRODUCTION

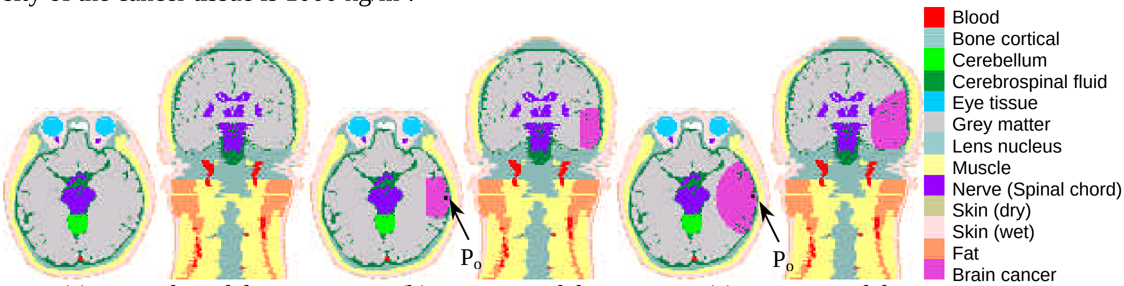
We consider EM absorption characteristics of the cancer patient as the special case of the public exposure under the uncontrolled environment. The effect of brain cancer on SAR has studied for exposures to plane waves of 350, 835, and 1765 MHz and a cellular telephone. We have measured the dielectric properties of some kinds of cancer tissues including the brain cancer [1]. The measured data of the brain cancer are ε_r=65.915, σ=1.032 (@350 MHz), ε_r=63.259, σ=1.210 (@835 MHz) and ε_r=61.016, σ=1.712 (@ 1765 MHz). They are higher than those of white matter and gray matter.

A normal model without brain cancer and two patient models with different brain cancers in size and shape were considered. The normal model has been implemented with MR and CT images of a volunteer whose head shape was very close to the domestic (Korean) standard. The patient models were made by numerically implanting brain cancer tissue in the normal model.

The plane wave was assumed to be incident to the side that the cancer is located in the head and the polarization is parallel to the vertical axis. The incident E-field strength at each frequency was the same with the reference level of ICNIRP guidelines for human exposure protection [2]. The cellular telephone was simulated as a monopole antenna on a conducting box enclosed with dielectrics. SAR distribution, peak SAR, averaged SAR of each tissue type according to cancer size and frequency were investigated.

HUMAN HEAD MODELS

A normal head model and two patient models with brain cancer tissue of 40 g and 118 g, respectively were used as shown Fig. 1. The cell size was 2×2×2 mm^3 and the number of simulated time steps was ten cycles for 835 and 1765 MHz and five cycles for 350 MHz. patient model (PM) I was embodied by replacing dielectric properties (ε_r and σ) of FDTD cells enclosing point P_0 in gray matter of normal model (NM) with ε_r and σ of brain cancer until the mass of the cancer gets 40 g. This process is the same with spatial-peak mass-averaged SAR evaluation method of [3]. In case of PM II, the cancer tissue was implanted within the radius of 44 mm centering around P_0 in the gray matter. Wet skin, dry skin, cerebrospinal fluid, muscle, and bone cortical were not replaced with cancer tissue. As results, the mass of the cancer tissue in PM I and PM II is about 40 g and 118 g, respectively, assuming that the mass density of the cancer tissue is 1000 kg/m^3.



(a) Normal model (b) Patient model I (c) Patient model II

Fig. 1. Human head models

PLANE WAVE EXPOSURE

The multi-layered structure consisting of air, muscle, brain cancer, and gray matter with infinite area and each finite thickness was analyzed as a preliminary study. It shows variation of EM absorptions near the cancer according to the thickness of the cancer. We can estimate that the maximum 1 g SAR is generally greater when the cancer tissue exists as shown in Fig. 2.

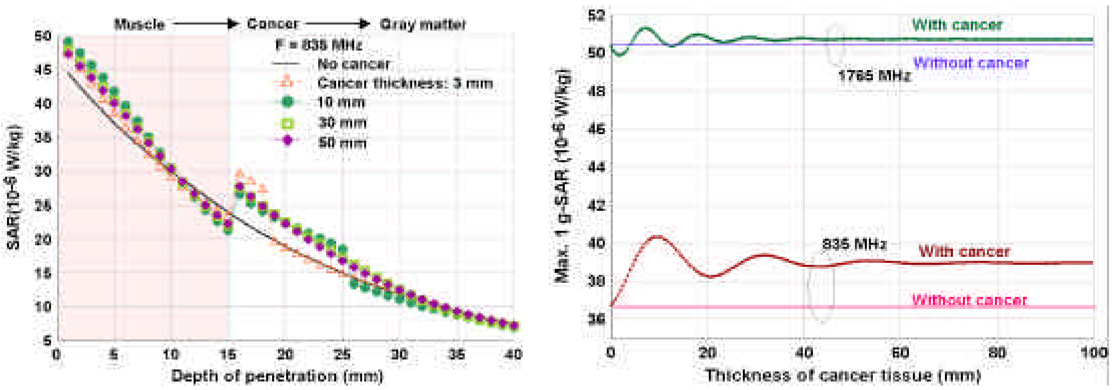
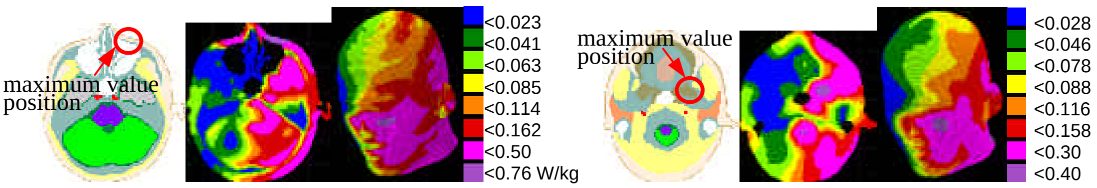


Fig. 2. Thickness of brain cancer and maximum 1 g SAR

Three frequencies of 350 MHz roughly known as the resonance frequency of a human head [4], 835, and 1765 MHz were considered for plane wave exposure.



(a) 1 g averaged SAR (b) 10 g averaged SAR

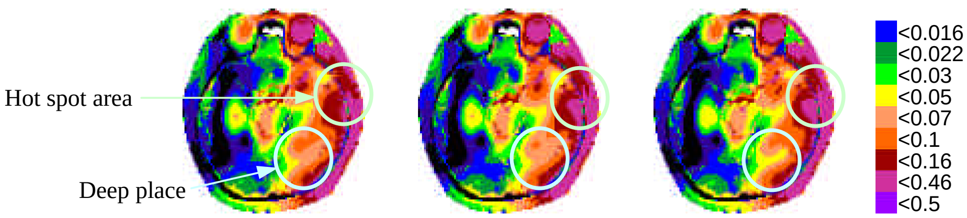
Fig. 3. SAR distributions for the normal model at 350 MHz

Fig. 3 shows the mass-averaged SAR distributions in NM at 350 MHz. We need to note that the maximum 1 g SAR occurred in the skin near the maxillary sinus but 10 g peak SAR did at a deep place (muscle-transverse fiber) in the head due to the head resonance. These positions of 1 g or 10 g maximum SARs were the same with those of PM I and PM II. With the increase of the cancer mass, peak SAR and tissue averaged SAR of eye tissue and lens nucleus became greater but averaged SAR values were lower for tissues at deep places in the head such as gray matter and nerve. Tissues with clear SAR variation, compared with those of NM are summarized as follows:

1) peak SAR of eye tissue; 1.9 % ↑ (PM I), 4.7 % ↑ (PM II)
2) averaged SAR of eye tissue; 1.9 % ↑ (PM I), 2.9 % ↑ (PM II)
3) peak SAR of lens nucleus; 0.9 % ↑ (PM I), 2.7 % ↑ (PM II)
4) avg. SAR of lens nucleus; 1.7 % ↑ (PM I), 3.4 % ↑ (PM II)
5) avg. SAR of gray matter; 2.9 % ↓ (PM I), 7.4 % ↓ (PM II)
6) avg. SAR of nerve; 1.3 % ↓ (PM I), 3.9 % ↓ (PM II)

The peak SAR and the averaged SAR of the brain cancer of PM II showed 13.9 % and 9.8 % increase, respectively than those of PM I. The maximum 1 g SAR of PM I and PM II showed 1.1 % and 2.3 %, respectively.

SAR distributions on the horizontal plane of Fig. 1 at 835 MHz are compared in Fig. 4. We can see that the bigger the cancer tissue is, the hot spot area is a little larger while the lower SAR at the deep place of the head appears. These phenomena are similar to those of Fig. 2. The reason of the greater SAR on the surface is since the incident field undergoes the greater reflection from the cancer tissue with higher permittivity and conductivity than those of the origin tissue, gray matter. Therefore, the field in deep area of the head that has passed through the cancer tissue becomes weaker.



(a) Normal model (b) Patient model I (c) Patient model II

Fig. 4. SAR distributions for plane wave exposure at 835 MHz

For exposures to plane waves of 835 and 1765 MHz, SAR of most of tissues showed slight variation of SAR and decreased SARs were observed for a few tissues in deep places of the head. Tissues with clear SAR variation, compared with those of NM as follows:

1) averaged SAR of cerebellum; 0.6 % ↓ (PM I), 4.9 % ↓ (PM II) at 835 MHz
2) averaged SAR of gray matter; 5.8 % ↓ (PM I), 9.6 % ↓ (PM II) at 835 MHz
   9.9 % ↓ (PM I), 17.4 % ↓ (PM II) at 1765 MHz
3) peak SAR of cerebrospinal fluid; 6.5 % ↓ (PM I), 6.9 % ↓ (PM II) at 1765 MHz
4) peak SAR of gray matter; 23.9 % ↓ (PM I), 42.5 % ↓ (PM II) at 1765 MHz
5) averaged SAR of nerve; 3.4 %↓ (PM I) 6.9 % ↓ (PM II) at 1765 MHz

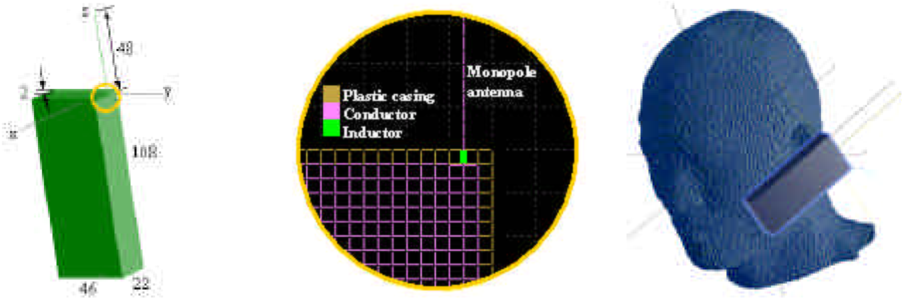
The peak SAR and the averaged SAR of the brain cancer of PM II showed 29.0 % increase and 20.5 % decrease at 835 MHz, respectively than those of PM I. At 1765 MHz, the averaged SAR decrease of 33.2 % appeared but the peak SAR was not varied.

MOBILE PHONE EXPOSURE

From simulation results for plane waves, we can see that SAR rising trend by brain cancer in a head was weaker for higher frequency. Therefore, only the cellular telephone was considered as a local exposure source. It was assumed to operate at 835 MHz and designed by analyzing the reflection coefficient. The plastic casing was simulated with dielectrics of ε_r=4.0 and the inductor of 33 nH was used for impedance matching. The sinusoidal voltage corresponding to the antenna input power of 1.0 W was applied to the source point on the top surface of the phone body using the coaxial feeding method.

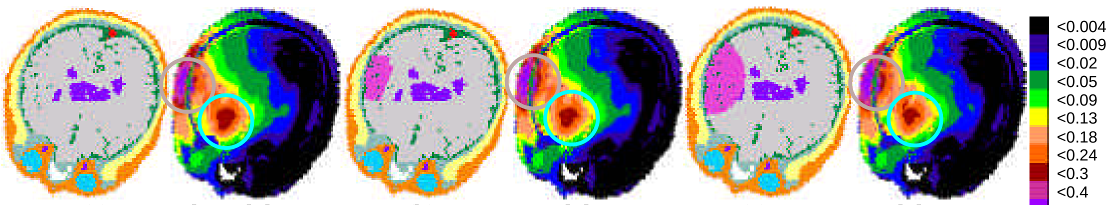
The touch position as the test position of a mobile phone was selected. Fig. 6 shows SAR distributions in the head models and the trend is similar to that of exposure to plane wave at 350 MHz. Cases with a clear SAR variation, compared with those of NM were as follows:

1) averaged SAR of cerebellum; 12.2 % ↓ (PM II)
2) peak SAR of eye tissue; 5.7 % ↓ (PM I), 7.4 % ↓ (PM II)
3) peak SAR of gray matter; 30.5 % ↓ (PM I), 52.6 % ↓ (PM II)
4) averaged SAR of gray matter; 26.7 % ↓ (PM I), 51.7 % ↓ (PM II)
5) peak SAR of lens nucleus; 3.7 % ↓ (PM I), 7.4 % ↓ (PM II)
6) peak SAR of nerve; 2.6 % ↓ (PM I), 10.9 % ↓ (PM II)
7) peak SAR of nerve; 3.1 % ↓ (PM I), 12.5 % ↓ (PM II)



(a) Phone model (b) Feeding part (c) Test position

Fig. 5. Phone model and test position



(a) Normal model (b) Patient model I (c) Patient model II

Fig. 6. SAR distributions in the head models exposed to cellular telephone

The peak SAR and the averaged SAR of the brain cancer of PM II showed 3.7 % and 3.2 % decreases, respectively and these variations are minute, compared with those of plane wave exposures.

CONCLUSIONS

We measured the dielectric properties of brain cancer and they were different with normal brain tissues. This paper treated numerically with the effect of brain cancer on SAR in a head at some RF frequencies, as a special case of the public exposure under the uncontrolled. In most cases considered, we could not find remarkably higher absorption in a patient's head due to the brain cancer and SAR decreases appeared in deep areas of the head such as cerebellum, gray matter, cerebrospinal fluid, and nerve. However, at 350 MHz, the increased maximum 1 g SAR and the more absorption in some important organs such as eye tissue and lens nucleus have been observed.

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